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## FLAT PLATE COLLECTOR DESIGN FOR THE CENTRAL U. S.

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### Abstract

An efficient design for both heating and cooling of an average sized residence is presented. The main source of energy is derived from a large roof top flat plate collector built into the roof structure of the house. The amount of solar energy collected is stored in a combination of hot air and hot water storage system located underneath the house. An auxiliary electric heating coil is built into the solar heating system for use in any extended period of cloudy and inclement weather. The system is so designed as to satisfy the two key requirements for any successful solar house, namely, ECONOMIC FEASIBILITY and RELIABILITY. Materials used for collectors, working fluids, storage equipment, etc. are readily available in lumber yards. The cost of the solar system is kept to a minimum and can be compensated by architectural design and construction savings through the use of the collector itself as the main roof structure. It is believed that the cost of this solar house will not exceed that of a residential dwelling of comparable size and quality in Missouri. However, the saving in fuel consumption will be substantial, up to 80%.

### Introduction

The amount of solar radiation reaching the U. S. daily is more than a thousand times larger than our daily energy consumption. However, in the past, sunlight as an energy source has not been tapped significantly for performing mechanical work, for the following reasons:

- (1)- Sunlight is not continuous at any location. Energy collected during the sunlight hours must be stored for night use;
- (2)- Conversion of sun energy into mechanical and electrical work is very inefficient. The conversion efficiency for the most modern photocells is 10-15 % at best, and the maximum theoretical efficiency has been calculated to be only 24%;
- (3)- Solar energy has a low intensity. It requires about 50 square miles of solar collector area to generate 3,500 megawatts of electric power, just enough to satisfy the electrical needs of a city of the size of Los Angeles.

On the other hand, solar energy is plentiful and pollution-free. The only form of pollution is the esthetic pollution arising from extensive collector areas, which could destroy the beauty of our landscape.

Recent research has been concentrated on two main objectives: to provide heat and electric power to the nation through utilization of solar energy. Ambitious programs have been initiated to collect high temperature solar energy to generate electricity. These programs often require elaborate systems and designs to collect the sun's energy and to convert it into electrical power. To use solar energy to heat and cool residential homes, on the other hand, does not require expensive equipment. Present state of the art is quite adequate to make solar heating and cooling very competitive with conventional methods. In this paper, I would like to discuss the merits and promises of such a house.

### Design Philosophy

Technology for using solar energy for water and space heating has been worked out for years. Recently, solar-powered houses are springing up in Delaware, Colorado, Florida, and Pennsylvania, with plans for others on the drawing boards. Our objective in this program is to design and build a solar house that meets all specific requirements for the climate and other geographic characteristics of Missouri and surrounding States in the Mid-West. Further, we hope to meet some of the most basic requirements for public support and acceptance of such a house. To gain a wide public support and acceptance, it is imperative that we give the public whatever they want. But usually, when we present to the people a prototype solar house, they often find the following objections:

- (1)- Solar houses are at best some oddities, with unacceptable architectural design. They are not the kind of homes people would like to live in.
- (2)- Solar houses are too expensive. It is imperative that we must keep the cost of the solar system down to a minimum. For example, a \$10,000 solar system to be added on to the current mortgage of the house would amount to more than \$100 extra in mortgage payment, which is more than what most families pay for their utilities in the coldest months.
- (3)- Solar systems are not reliable. It is evident that the general public wants winter and summer comfort with the assurance of back-up systems, and without frequent costly repairs.

Furthermore, since solar energy is diffuse and of a very low intensity, the cost of a solar system would rise exponentially with the heating and cooling loads and with the degree of self-sufficiency in providing all the power requirements of the house. Thus it would be impossible to keep the cost down if, for example, we must provide electricity for cooking and light, since the photovoltaic cells are still the most costly components in the energy conversion process. To reduce the heating and cooling loads as much as possible, we must follow as closely as possible all the energy saving tips in home construction. They are listed as follows:

#### 1)- Siting:

- Built your house on the sunny side of a hill, tucked into the hill;
- Keep all surrounding trees, especially to the North for wind breakers and to the West for shielding the hot sun in the summer;
- Face short walls to the North, preferably without any windows;
- Face South all living rooms, kitchen, and family rooms, face East all bedrooms.

#### 2)- House Design:

- Build your house with a minimum amount of exterior walls for a maximum living area. A circular house would be best, but it is usually more expensive to build, due to increase in labor cost. The next best design is a two-story, square or rectangular in shape.
- The first floor must be well insulated from the basement or crawl-space.
- Design all living area (kitchen, living room and family room) open to a large expanse, for it is

much easier to heat a large room than several small ones.

-Provide good ventilation under roof and in the attic.

### 3)- Materials:

- Use light colored shingles;
- Use a minimum amount of windows, all windows must be of thermopane double insulating glass;
- Provide at least 10" insulation on ceiling and 4" or 6" with vapor barrier on outside walls;
- Heat ducts must be run inside the insulated area;
- Use 5/8" wood siding and caulk all cracks;

### 4)- Location of appliances:

- Use heat retrieval, open air cycle heating systems;
- Install exhaust fans in all bathrooms and kitchen;
- Use heat from the fireplaces to heat all the rooms in the house, including the upstairs bedrooms;
- Use glass firescreens on all fireplace openings
- Place stove, washer, dryer away from exterior doors and walls;
- Do not place refrigerator near heat registers or in direct sunlight areas.

With the above precautions, we are able to reduce the power load of a standard three bedroom house by one half, as shown in Tables 1 and 2.

After surveying the popular opinion on house design and styling, we have arrived at the conclusion that most American families still cherish a single detached family homes of early Colonial or New England architecture, similar to the one shown in Figure 1.

### Solar Collector

In the Mid-West, the amount of sun energy that could be collected at noon hour varies from 280 to 300 BTU/hr-sq.ft. A roof-top solar collector of 1,000 sq.ft. in area would collect enough energy in one good sunny day to heat the proposed house for at least three or four cloudy days. The collector is built as a part of the roof structure so that substantial savings on plywood and shingles may be used to compensate for the cost of sheet metals and glass or plexiglass cover. Details of construction is given in Figure 8. The collectors are fabricated of wooden frames and utilizes black-painted corrugated metal plates as the absorbers. To prevent breakages and to minimize maintenance costs, instead of the glass cover one may use a nylon-reinforced solar resistant, plastic-fabric material. The total annual heat collected, as shown in Fig.2, is only about 6% short of the power requirement in the months of December and January but more than enough to cool the house in the summer months.

### Heat Storage

With the reduced heat load (276 BTU/hr/°F) of the house, it requires only about  $2.5 \times 10^5$  BTU/day to keep the inside temperature at 70 °F when the outside temperature is at 20 °F. In order to store 1 million BTU for four days use, we need about 50,000 lbs. of water or a volume of 1,000 cubic feet. A concrete storage tank (10' x 10' x 10') insulated with 6" fiberglass bats may be constructed in the basement level. Additional heat storage can be obtained by using rock, but it will require twice the volume (about 2,000 cu.ft.) of water to store  $10^6$  BTU. We have discarded the use of Glauber's salt or other chemicals in order to keep the cost down to a minimum. An auxiliary storage tank (600 gallons) is used for hot water in the winter and as the condenser-evaporator for the  $\text{NH}_3\text{-H}_2\text{O}$  air conditioning system in the summer.

### Heating and Cooling

Water is circulated from the storage tank through the collector loop at a rate of 10 lbs/sq.-hr, by a circulating pump controlled by a comparative-type thermostat which will energize the pump when the collector temperature exceeds that of the storage tank by 50°F. The heat energy, through a heat exchanger, is carried through the living area in the form of warm air by a fan-coil unit having a variable speed blower motor. An auxiliary electric heating coil is inserted into the main plenum which will be energized when the air temperature falls below 68 °F. Domestic hot water is supplied through a coil immersed in the smaller water tank. As shown in Fig. 5, the fireplace is used as an auxiliary heating system. In order to save energy from the solar system, the warm air from the heat storage is distributed to all the rooms through the plenum surrounding the fireplace so that when the fireplace is being in use, the main blower motor of the main line is shut off when the air temperature around the fireplace is above 72°F.

For summer cooling, we use a  $\text{NH}_3\text{-H}_2\text{O}$  absorption air conditioner with the two water storage tanks as heat source and evaporator-condenser.(Fig.4)

The over-all diagram of the heating loop is shown in Fig. 3 and Fig. 7. The floor plans shown in Fig. 5 and 6 give the locations of heat registers around the fireplace into each room.

### Cost Analysis

Based on the labor and material market of Rolla, Mo. the cost of the solar collector (corrugated metal roofing material and glass or plastic cover) is about the same as the cost of plywood and shingles in a standard house. The only extra cost involved would be the labor cost for installation. The heat storage tanks would cost about \$1,000 while the duct work and the air conditioner is about the same as an electric furnace and air conditioner in standard houses. Even if we include the extra costs of thermopane windows and insulation, the total cost of our solar house would not exceed that of a standard house by more than \$2,000. This can be quickly recovered through savings in power consumption and utilities bills at a rate of \$50-75 per month, or roughly in about two and half years.

### Conclusion

It is feasible in the immediate future to build an economical and reliable solar house which will supply at least 75-80% of energy for heating and cooling with a minimum additional cost to the home buyer. The key element of such a house is to conform with the natural environment in minimizing energy needs and to use only cheap, commonly available building materials for heat collection and storage. Uses of auxiliary and supplementary heat sources must be incorporated into the design and construction of the house. Special attention must be paid to the esthetic and architectural values of the general public.

Table 1 - Heating Load

Exterior Areas	Standard House		Thermal House	
	U value (BTU/hr/ft <sup>2</sup> /°F)	Heat Loss (BTU/hr/°F)	U-value (BTU/hr/ft <sup>2</sup> /°F)	Heat loss (BTU/hr/°F)
1460 sq.ft.exterior wall	0.07	102	0.04	58
Windows, 140 sq.ft.glass	1.13	158	0.45	63
Ceiling, 1700 sq.ft.	0.068	116	0.027	45
Floor, 200 lin.ft.slabs perimeter	0.81	162	0.55	110
<b>TOTAL HEAT LOSS/°F</b>		<b>538</b>		<b>276</b>

Note: Standard house specifications: R11 insulation on walls,  
R19 insulation on ceiling

Table 2 - Cooling Load

Exterior Areas	Standard House		Thermal House	
	U-value & T	Heat Gain	U-value & T	Heat gain
Exterior Walls, 1460 sq.ft.	U=0.07 T=18.6°F	1900 BTUh	U=0.04 T=11.3°F	660 BTUh
Ceiling, 1700 sq.ft.	U=0.068 T=31.0°F	3580	U=0.0267 T=23.3°F	1057
Windows, 140 sq.ft.	U=1.13	3220	U=0.45	2380
<b>TOTAL</b>	<b>23 BTUh/sq.ft.</b>	<b>8700 BTUh</b>	<b>17 BTUh/sq/ft/</b>	<b>4097 BTUh</b>

Note: Temperature for the summer is taken as 95°F outside and  
75°F inside  
Windows for standard house are of single pane glass and for  
thermal house are of thermopane double insulating glass, Andersen

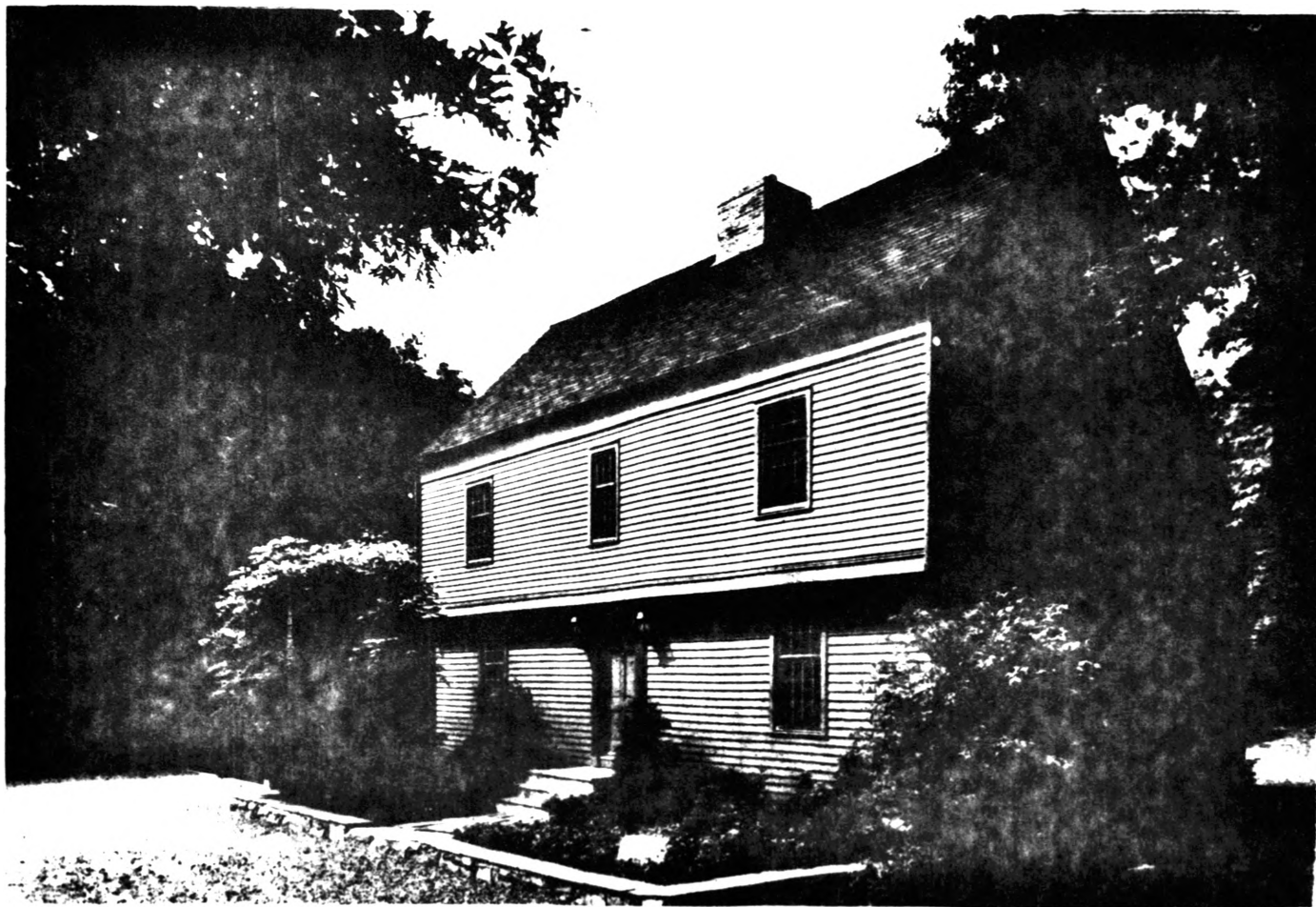


Figure 1. Front Elevation of a Salt-Box House

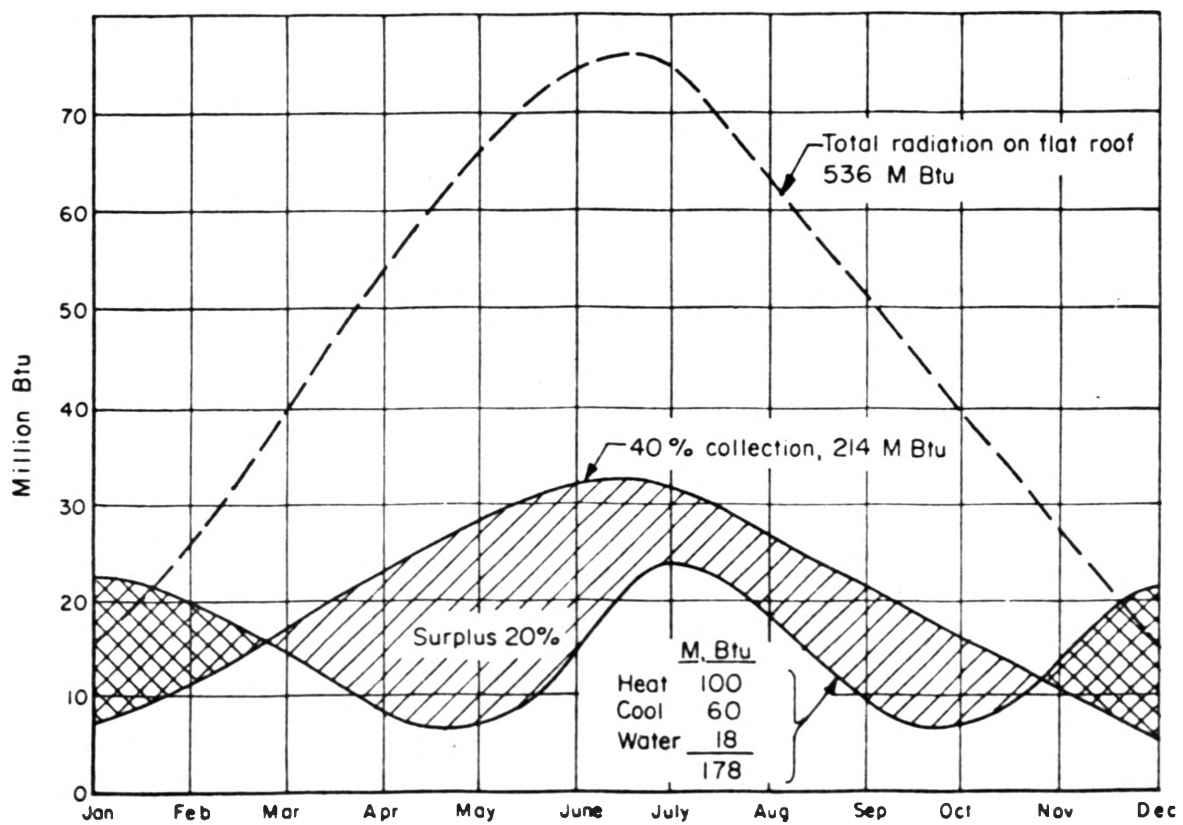
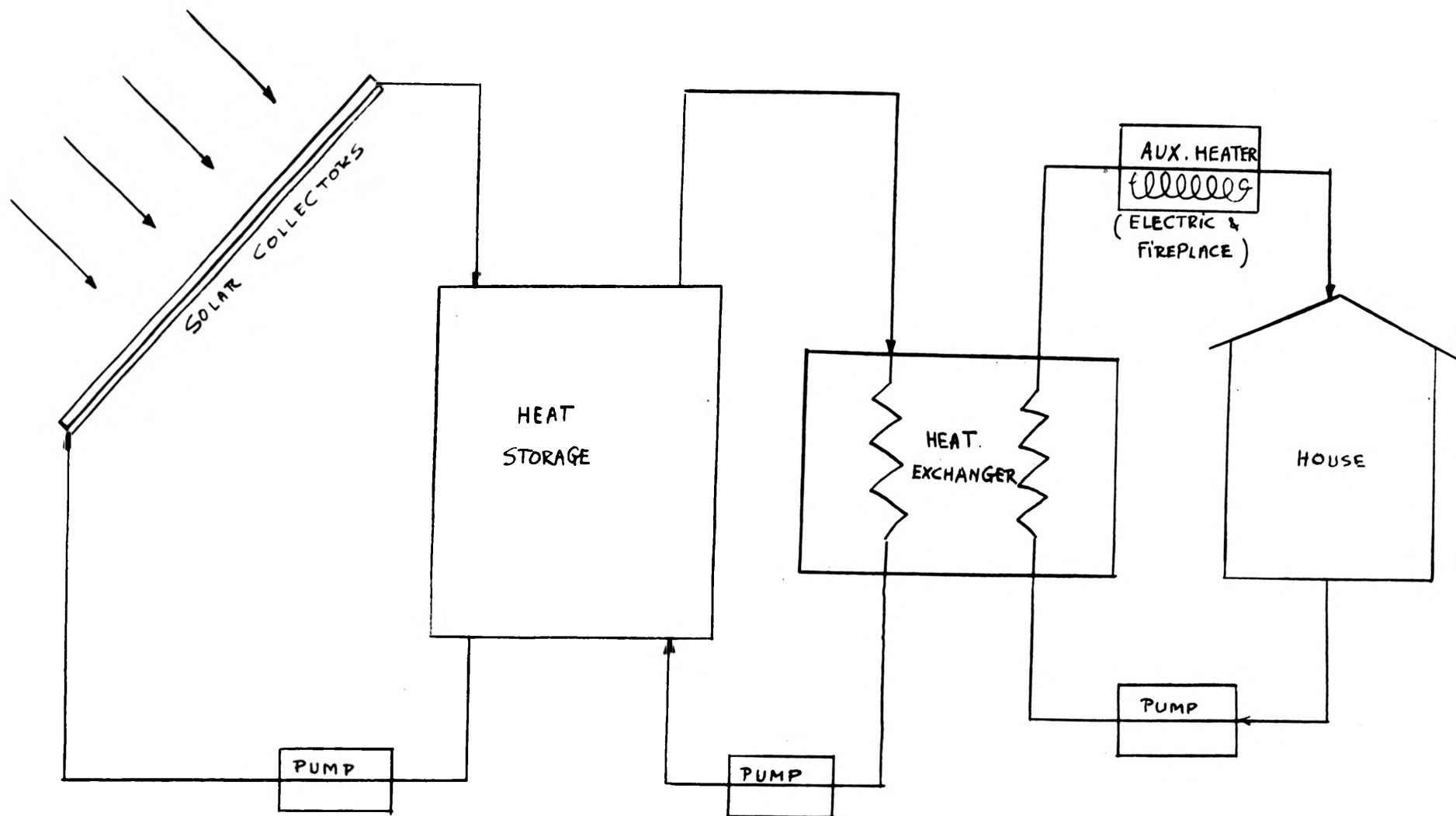


Figure 2.



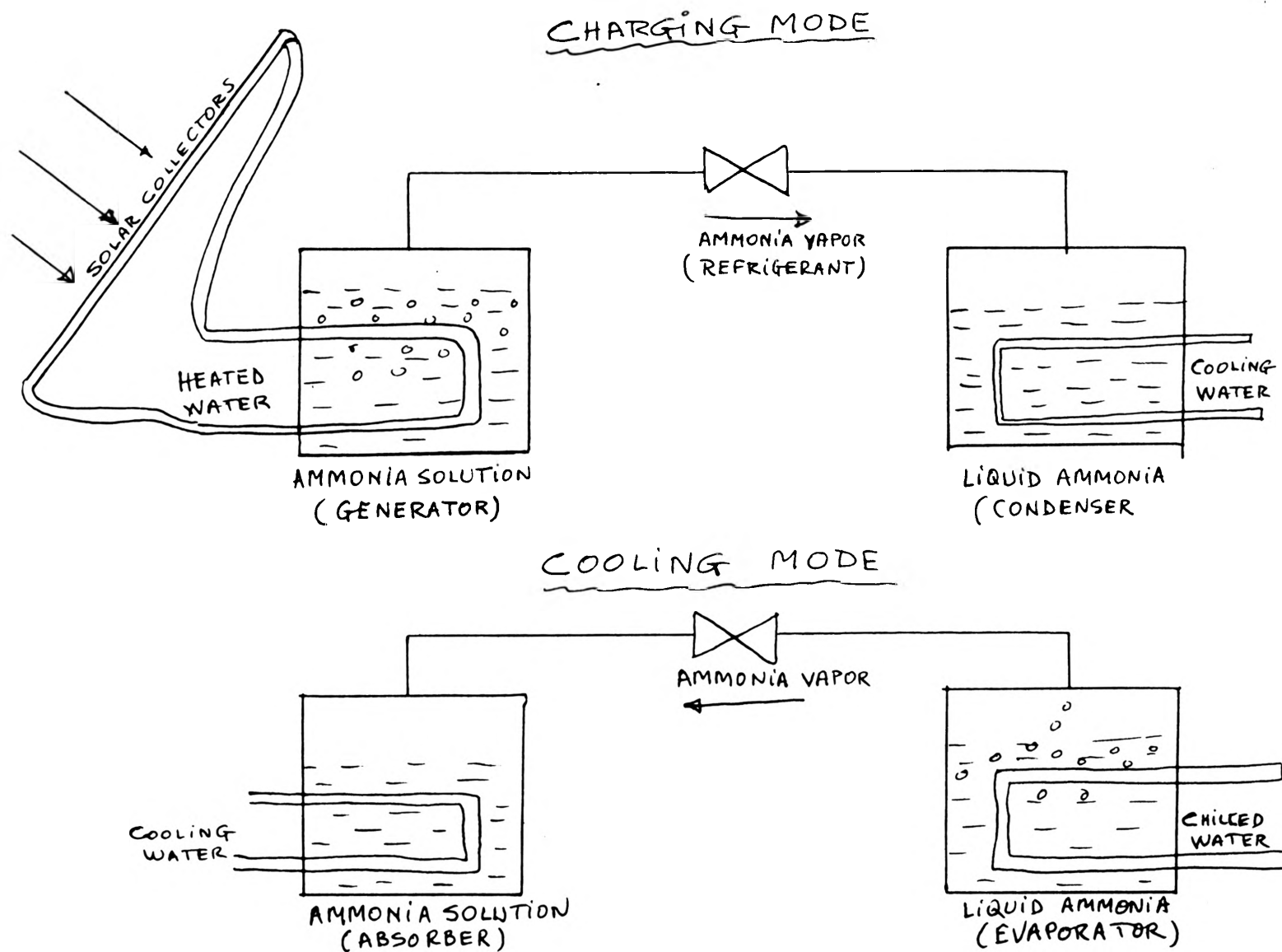


Figure 4. Schematic diagram for a  $\text{NH}_3\text{-H}_2\text{O}$  absorption air-conditioner

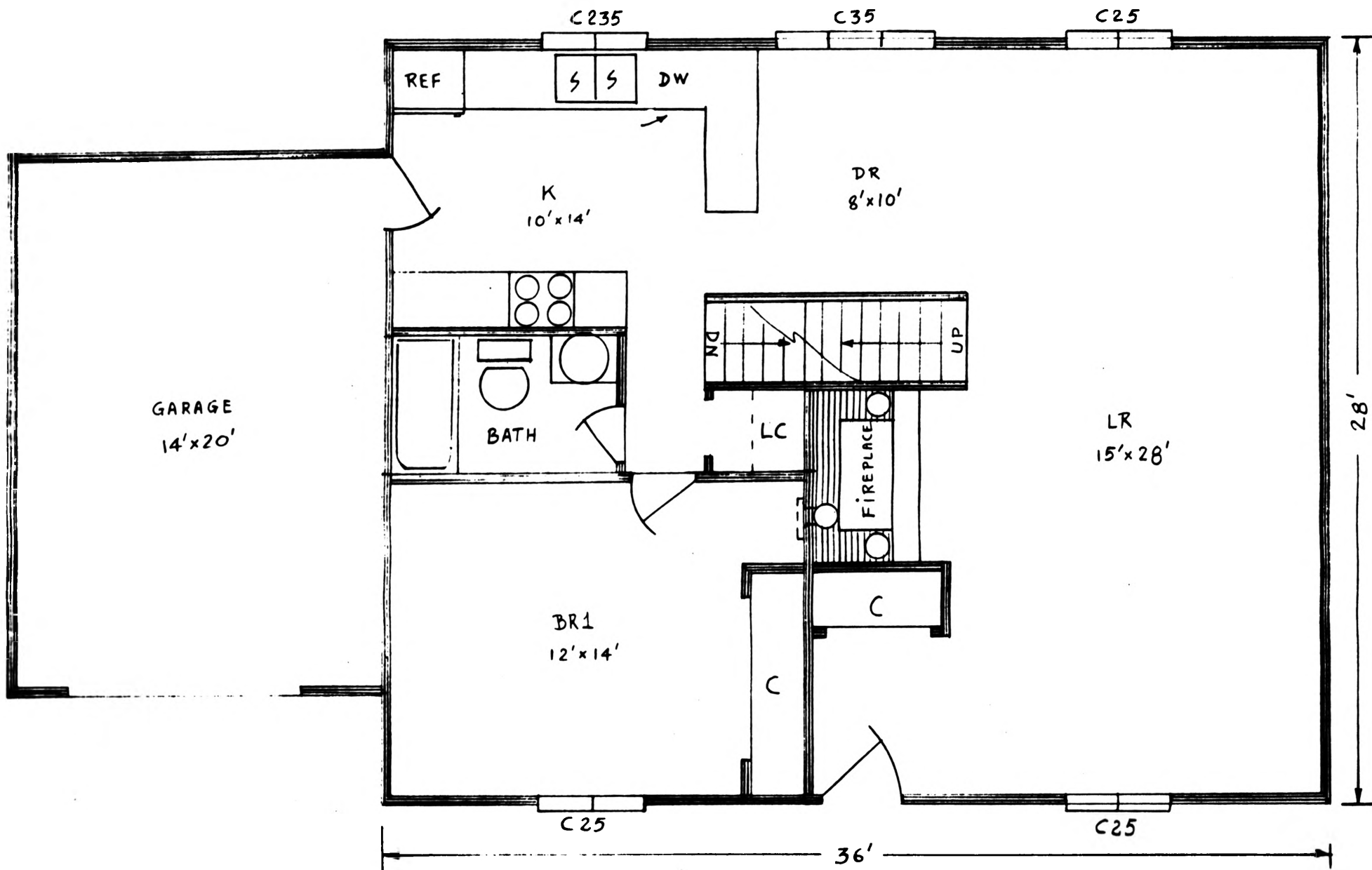


Figure 5. Floor plan for the 1st level



FIRST FLOOR = 1,008 SQ. FT.  
 SECOND FLOOR = 520 SQ. FT.  
 TOTAL = 1,528 SQ. FT.

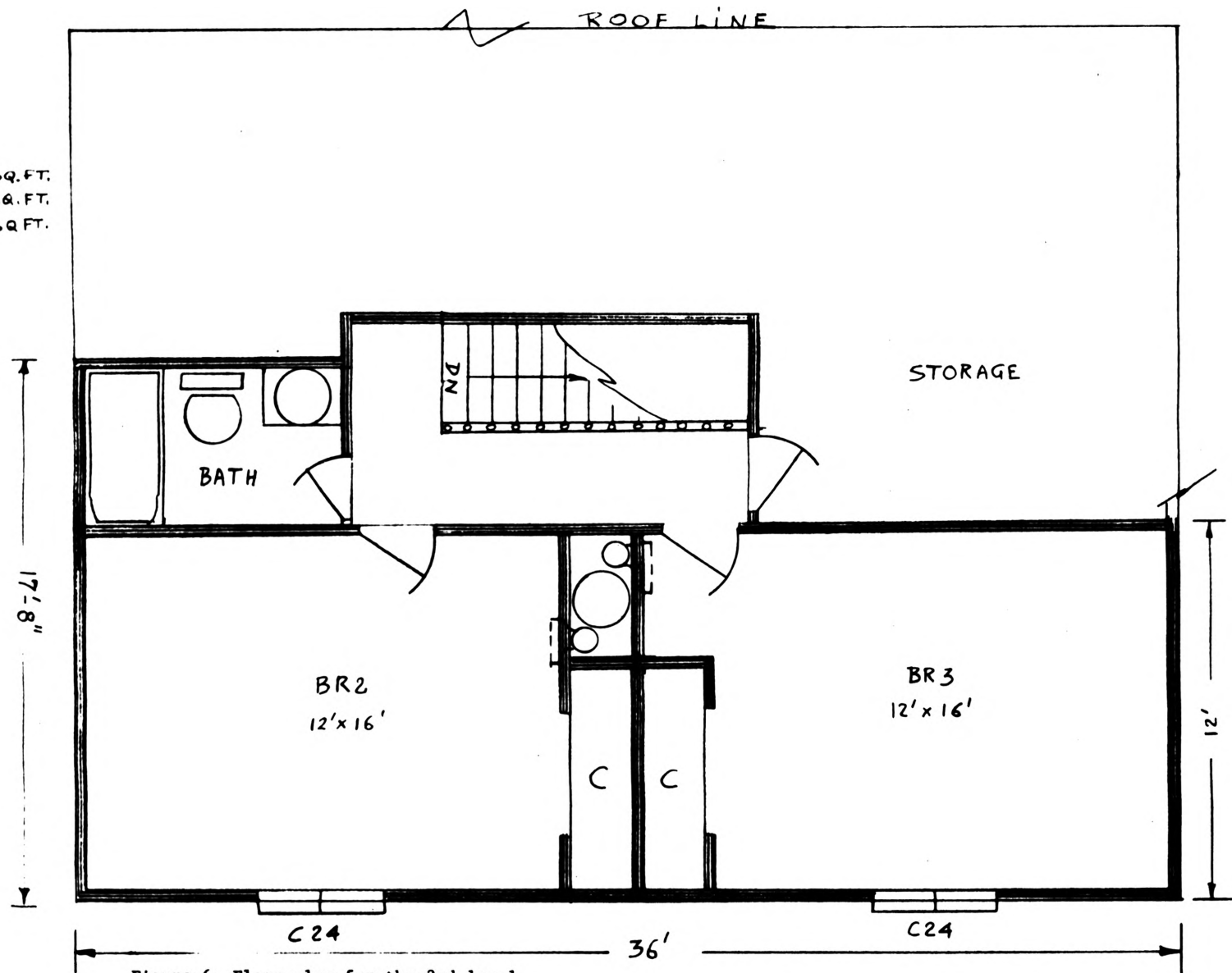
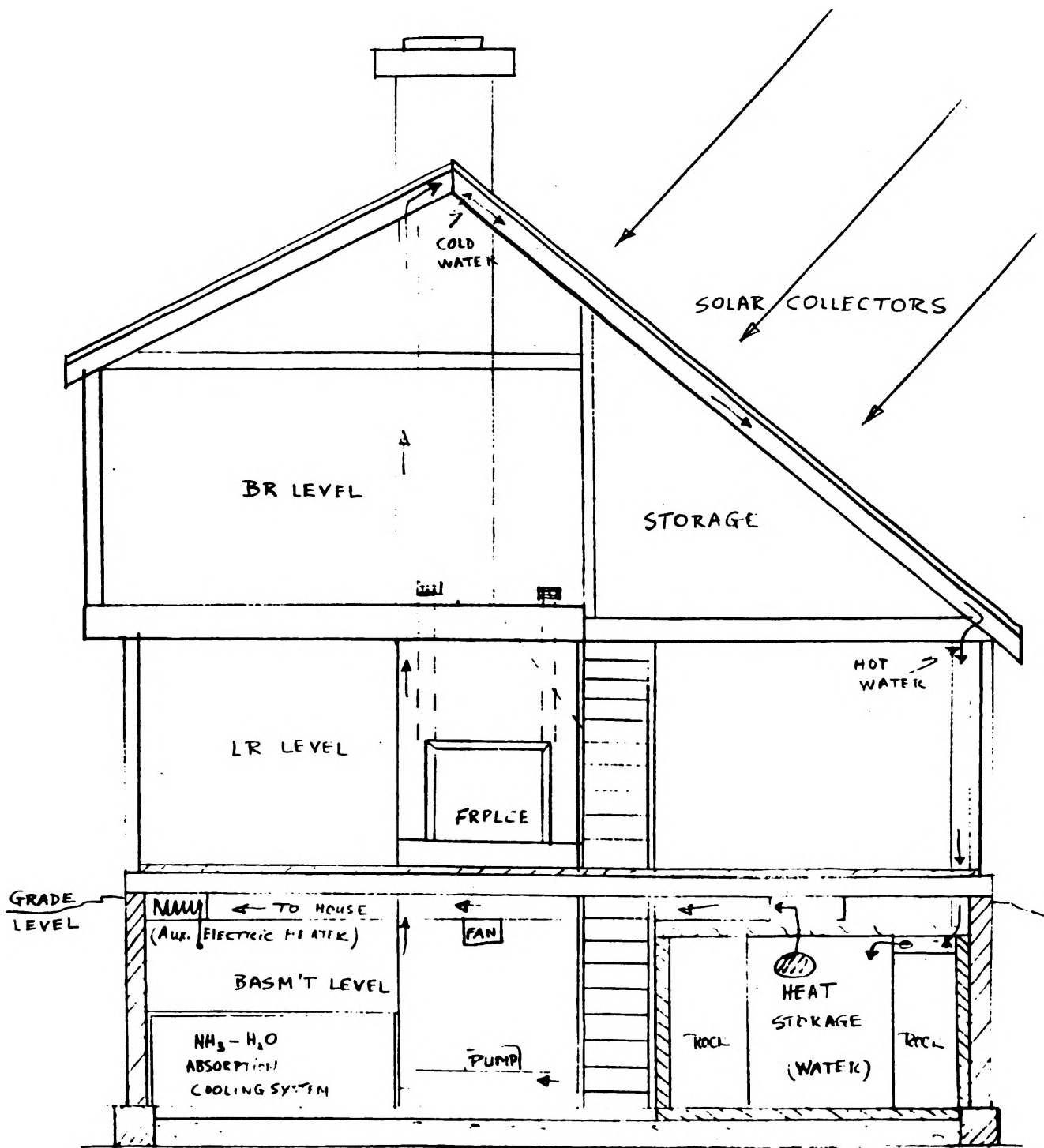


Figure 6. Floor plan for the 2nd level



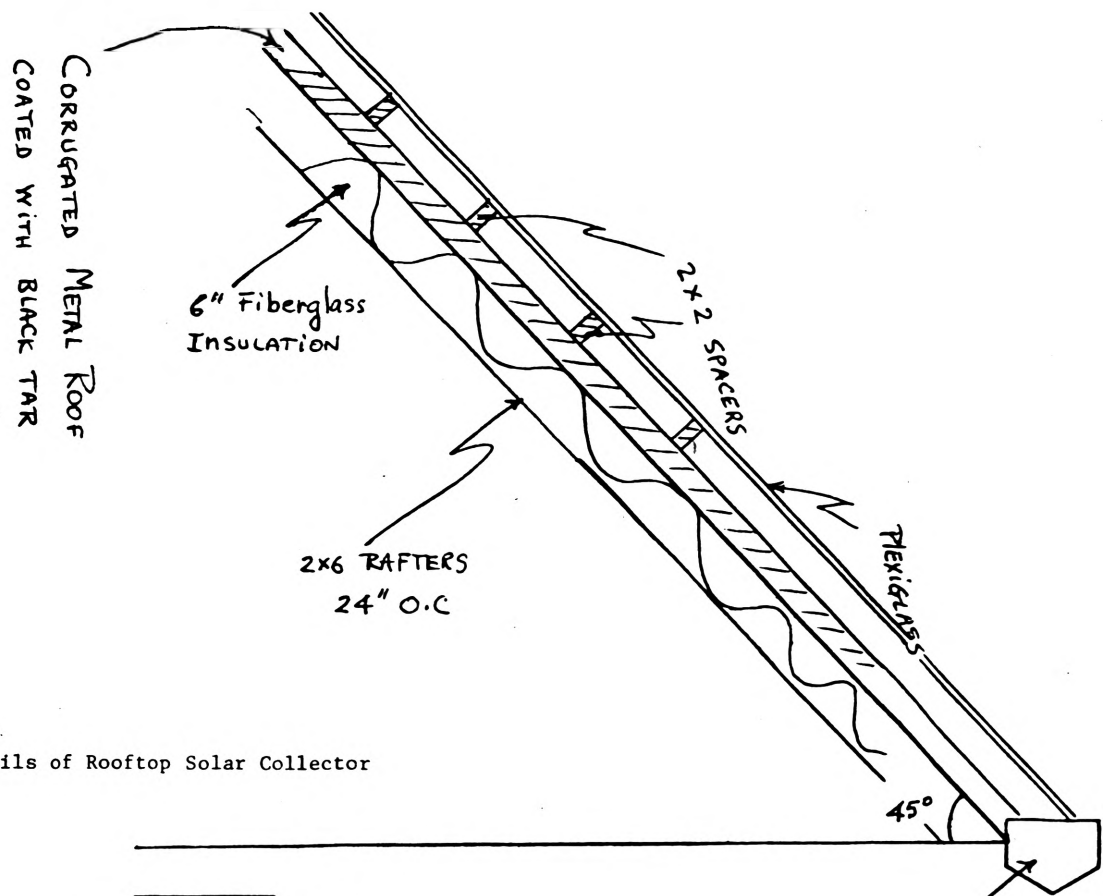


Figure 8. Details of Rooftop Solar Collector

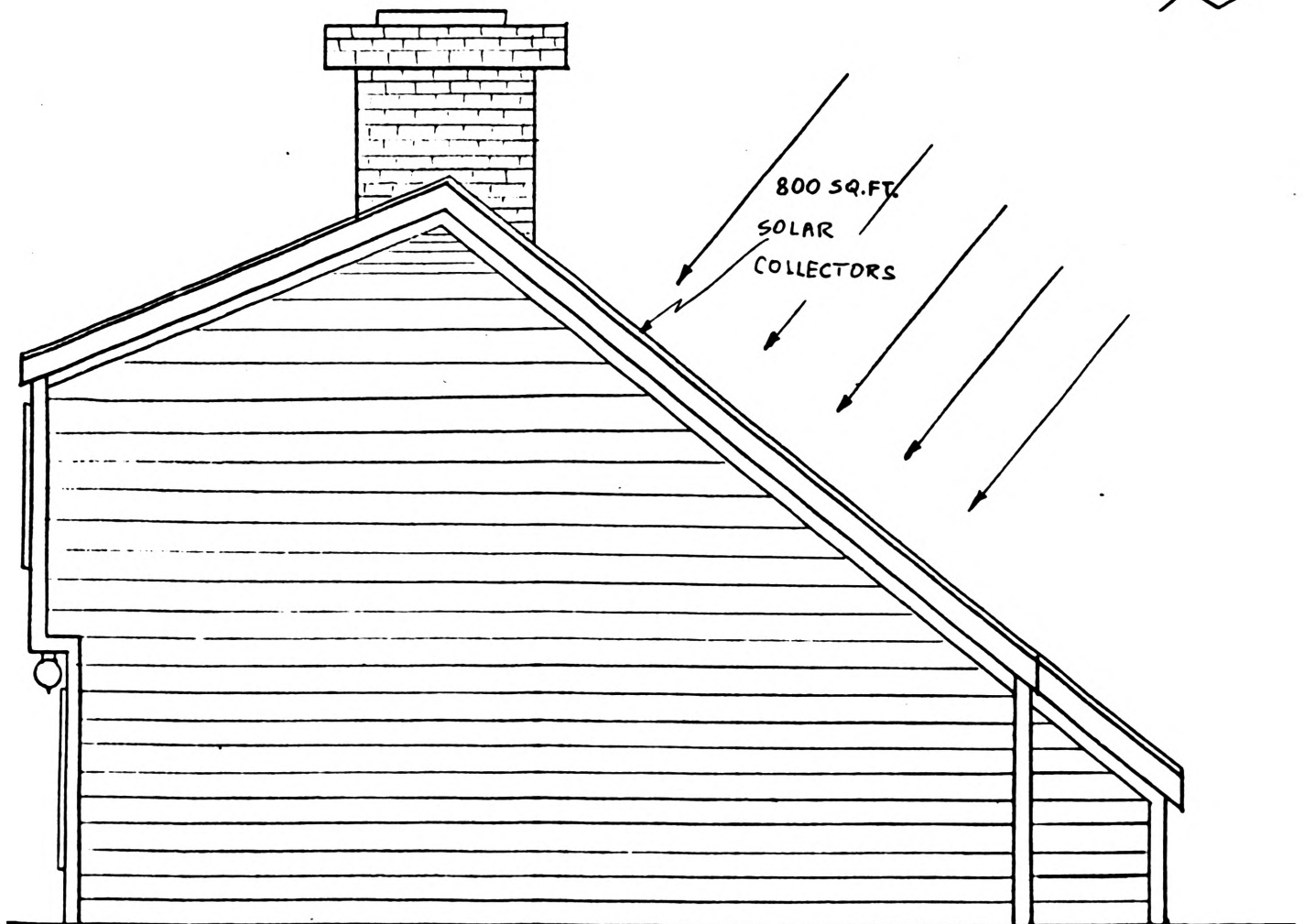
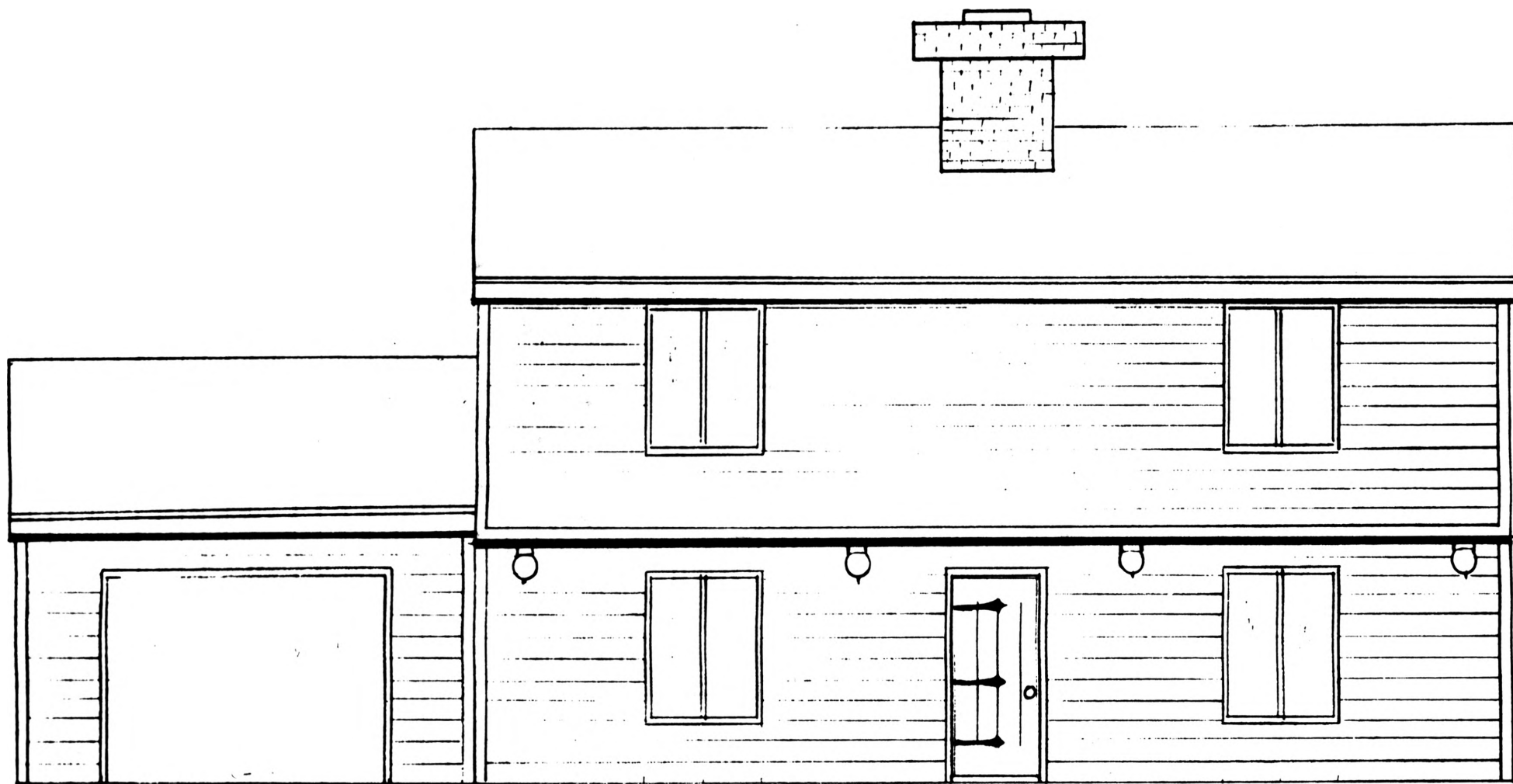


Figure 9. Side Elevation of the Solar House



FRONT ELEVATION

Figure 10. Front Elevation of the Solar House